A continuous fountain of cold Cs atoms for a primary frequency standard

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We are assembling a primary frequency standard based on an atomic fountain [1]. This fountain is original since it uses a continuous beam of laser cooled Cs atoms, while the other equivalent devices use pulsed operation. Ramsey resonance fringes have already been obtained and we are now in the process of optimising the system [2]. The latest results will be reported at the Conference.

The continuous atomic beam of laser cooled atoms (fig.1) is produced with a σ^+-σ^- moving molasses. Atoms are captured and cooled from a thermal cesium vapour at the intersection of three pairs of mutually orthogonal laser beams. One pair is horizontal (Ox) and is retroreflected by a roof prism inside the vacuum system. The other two pairs are in the Oyz plane and propagate at 45° with respect to the vertical [3]. Roughly $2 \cdot 10^8$ atoms/s are launched upwards and make a parabolic flight of 0.8 s. Their initial speed is 3.9 m/s and their longitudinal temperature is 50 μK.

After leaving the optical molasses, the atoms enter the microwave interaction region. A cylindrical, coaxial cavity, tuned to the atomic hyperfine transition frequency ($6S_{1/2}$, F=3-F=4, 9.2 GHz), provides two interaction zones. The first interaction ($\pi/2$ pulse) takes place while atoms move upwards, the second on their way down. The two interactions are separated by a free precession period of 0.5 s, yielding a Ramsey fringe width of 1 Hz.

The atomic fluorescence in a probe beam is used to measure the microwave transition probability. Ramsey fringes are obtained by scanning the frequency of the microwave magnetic field in the cavity near the nominal Cs frequency (9'192'631'770 Hz). Figure 2.a shows our first and preliminary results. The S/N ratio does not yet allow a detailed analysis of the fringes. However, their width (1Hz) is as expected and the decreasing contrast far from the central fringe is explained by the beam temperature, as demonstrated in fig.2.b by the theoretical Ramsey pattern in a 50 μK fountain.

Our effort is now concentrated on the optimisation of the flux, which depends critically on the atomic beam temperature. The effects of the residual magnetic field in the launching region have been measured and will be discussed. Measurements with an additional laser cooling beam applied to the atoms after they leave the optical molasses to reduce their "transverse" temperature and to tilt their trajectory will be reported.

The main advantages of the continuous fountain are the absence of "dead time" in the microwave interrogation of the cold atoms (which matters for the clock stability) [4] and the reduction of collisional shifts (which matters for the clock accuracy). These benefits would also play an important role in other applications such as atomic interferometers and inertial sensors.

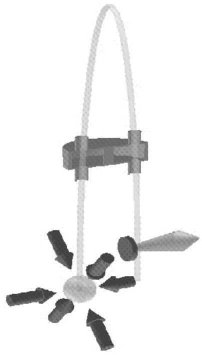

Figure 1: Basic configuration of the continuous fountain, showing the 6 cooling beams, the microwave cavity and the detection region.

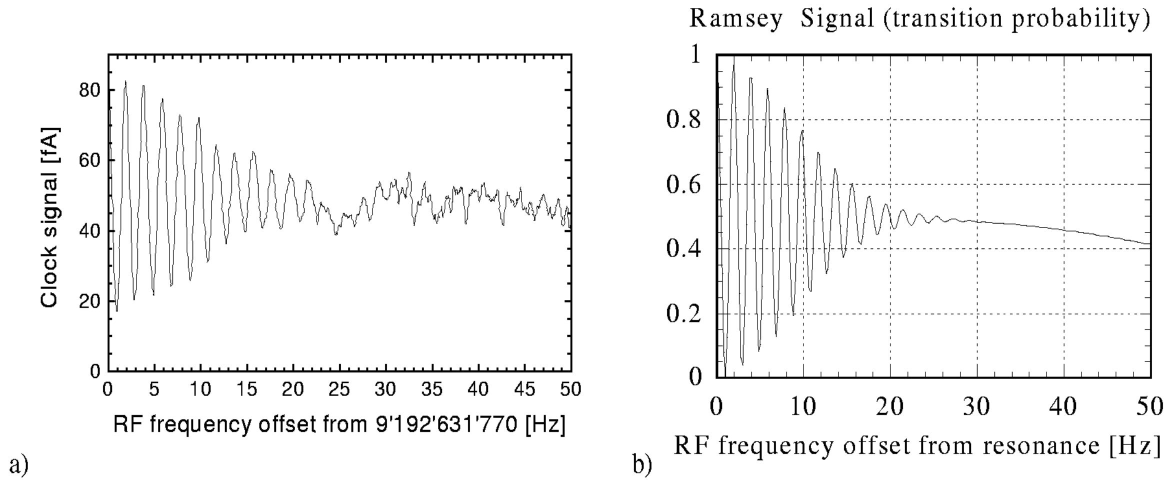

Figure 2: a) Ramsey fringes of the Cs clock transition in the continuous fountain. b) Calculated Ramsey pattern of a fountain beam with a temperature of 50μK.

[1] G. Dudle et al., *An alternative cold cesium frequency standard : the continuous fountain*, accepted for publication in IEEE Transactions on UFFC, 2000.

[2] G. Mileti et al., *Development of the ON/OFMET continuous Cs fountain standard: a progress report*, Procs of the 14th EFTF (European Frequency and Time Forum), Torino, March 2000.

[3] P. Berthoud et al., *Bright, slow, continuous beam of laser-cooled atoms*, Phys. Rev. A, R4241-4244, Dec. 1999.

[4] A. Joyet et al., *Theoretical study of the Dick effect in a continuously operated Ramsey resonator*, Procs of the 14th EFTF (European Frequency and Time Forum), Torino, March 2000.